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**HABITABILITY DATA HANDBOOK
VOLUME 2
ARCHITECTURE AND ENVIRONMENT**

**SUPPLEMENT 2****MAY 1973**

**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
JOHNSON SPACECRAFT CENTER**

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I. INTRODUCTION

This volume is a supplement to the Habitability Data Handbook, Volume 2 and Supplement 1 (MSC-03909). Data presented in these handbooks are still applicable as noted. For example, lighting, acoustics, temperature, and color requirements pertain to either a zero or artificial gravity environments. The data presented in this supplement is directed primarily at a zero-gravity environment with considerations for operations in a one-g environment. The data was obtained from simulated zero-gravity testing in a neutral buoyancy environment.

II. DEFINITIONS

A. GROSS VOLUME

Gross volume is that volume which would be available if all furniture items, storage modules, controls and control panels, and equipment were removed from the room leaving the room walls only.

B. NET VOLUME

Net volume is the usable room volume that remains when all furniture items are deployed as they are to be used and when all storage modules, controls, and equipment are in place.

C. ACCESS VOLUME

Access volume is that volume required for man to interface with a specific item of furniture, control, storage module, or equipment as they are positioned for use.

D. MAN'S REFERENCE AXIS

In zero gravity, the human body can be considered to be a free, inflexible body with six-degree freedom of motion. For this reason a reference system for the body is required to define the movements of the body in a zero-gravity environment. The axes and relative motions are illustrated by Figure II-1 and all references to man's axes in this document will be according to this system.

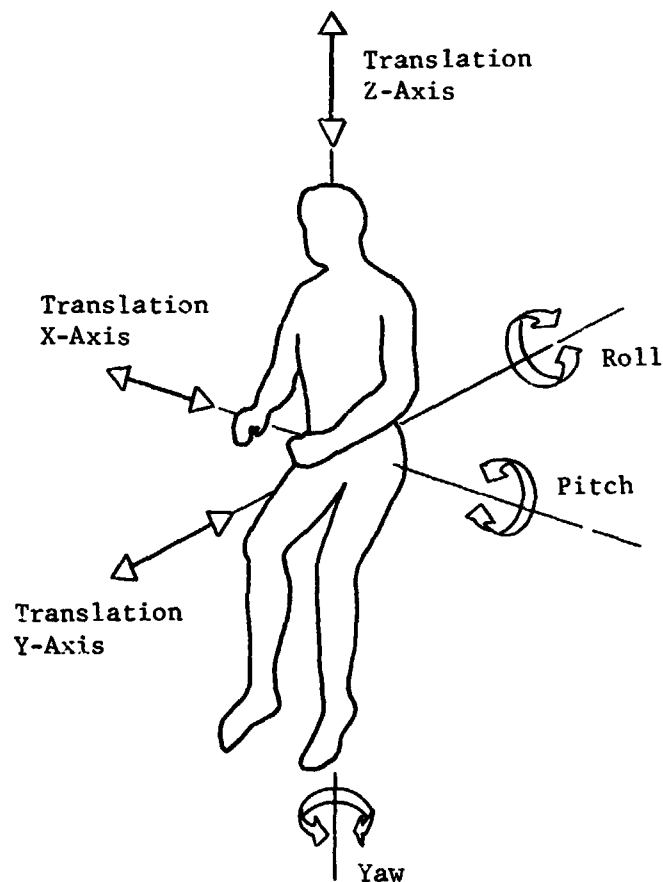


Figure II-1 Axes and Six Degrees of Body Motion in Zero Gravity

E. COUCH REFERENCE AXIS

When reference is made to the axes of a couch within this document the axes as defined by Figure II-2 will be used.

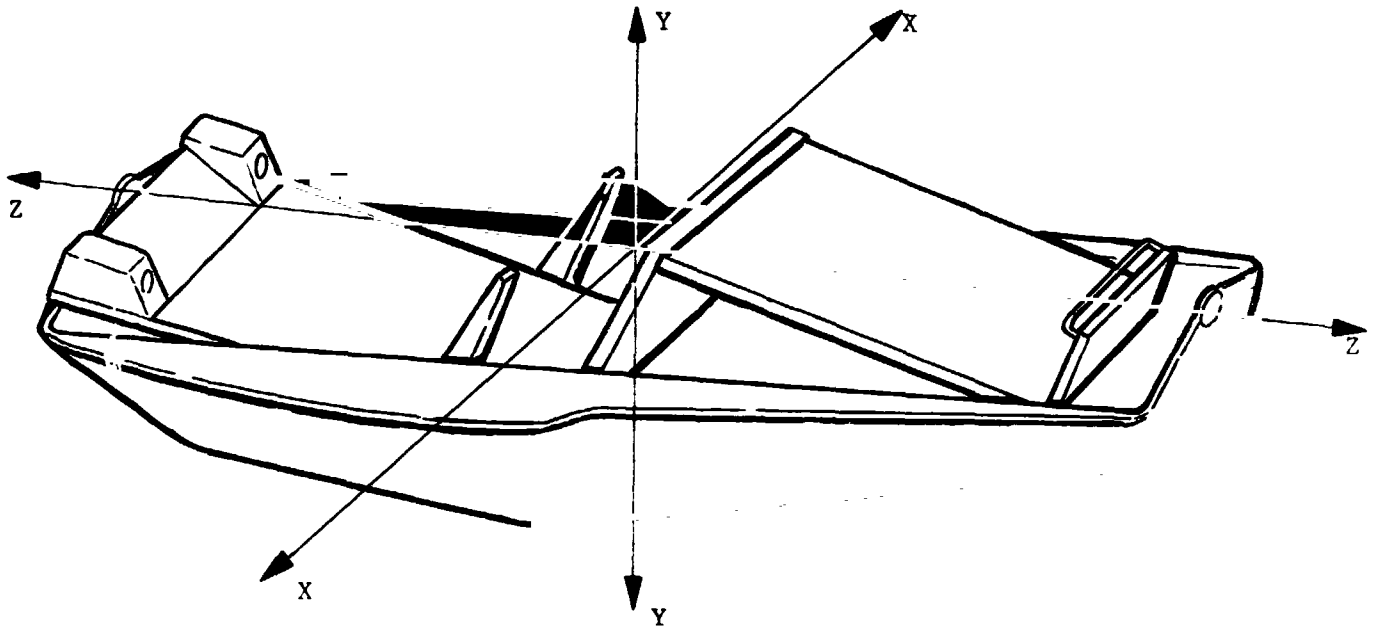


Figure II-2 Couch Reference Axes

F. VEHICLE REFERENCE AXIS

When reference is made to the axes of the vehicle within this document the axes as defined by Figure II-3 will be used.

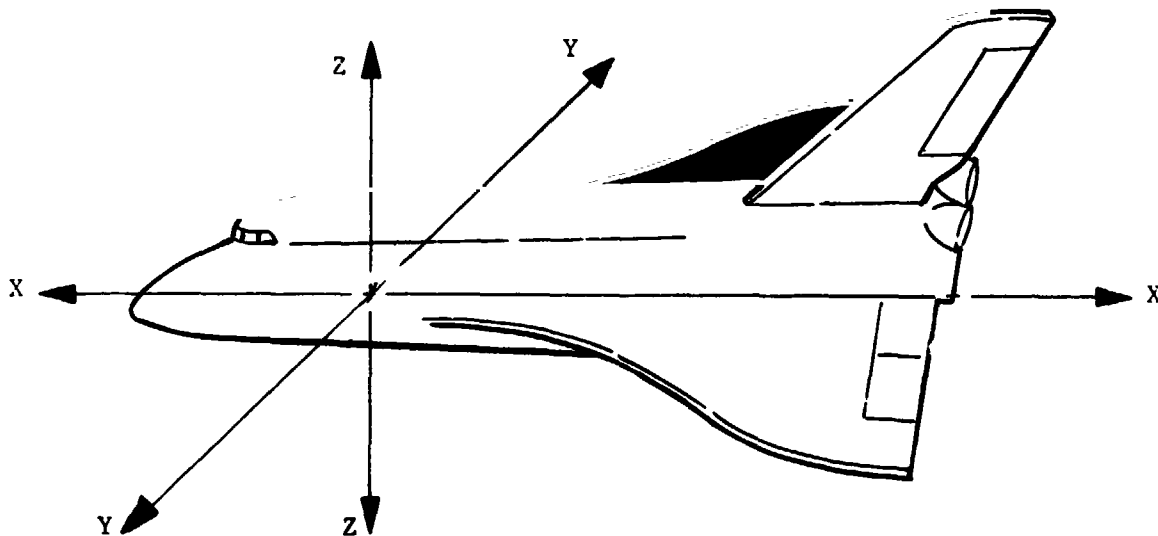


Figure II-3 Vehicle Reference Axes

III. RESTRAINTS/MOBILITY AIDS

The restraints/mobility aids depicted in the following paragraphs are required for the man-machine interface in a zero-gravity environment.

A. STANDING AT A WORK COUNTER

Figure III-1 shows a restraint system for a typical counter top task application. The toerail and handhold should be of the same shape with an elliptical cross-section of $\frac{5}{8}$ inch by $1\frac{1}{4}$ inch, length is dependent upon application with a recommended nominal of 18 inches. The handrail should be located in front of the counter top surface to keep the top surface clear and to provide a better hand hold for tasks below the counter top. Handrail location in front of the counter top also provides a palm-down or palm-up holding position by the user.

NOTE: ALL DIMENSIONS IN INCHES

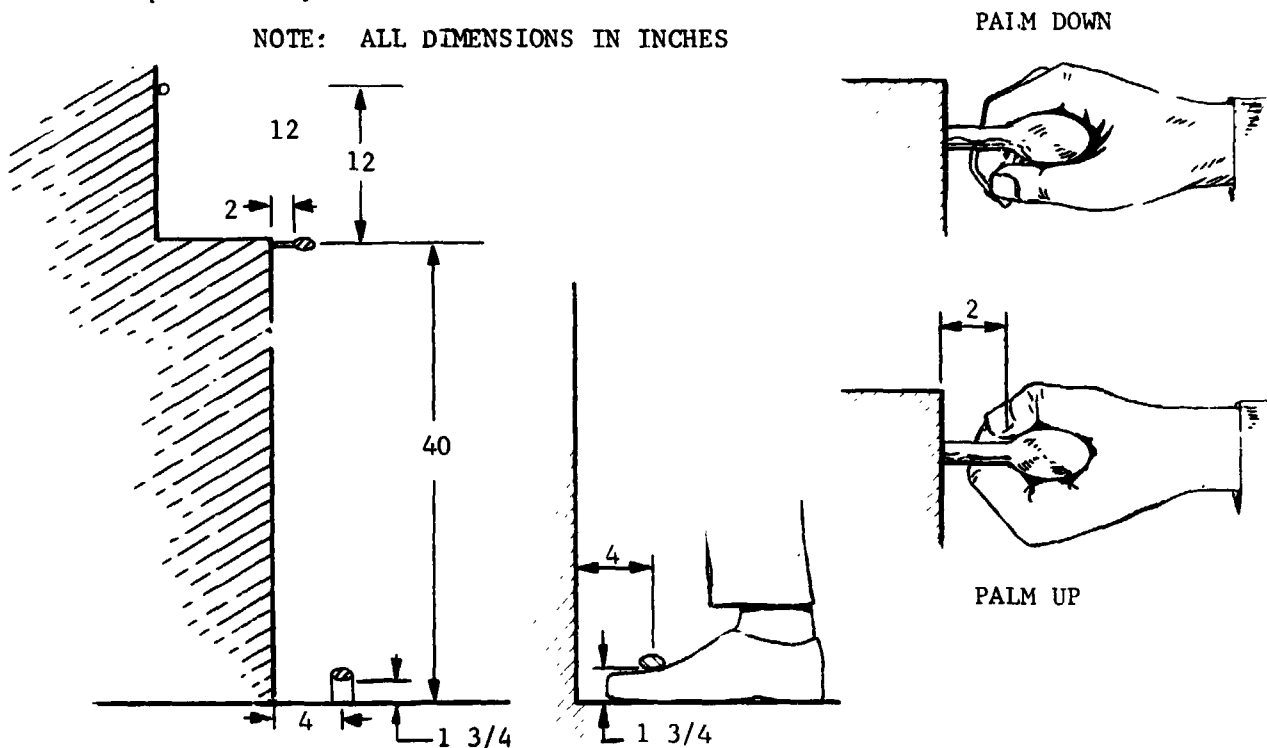
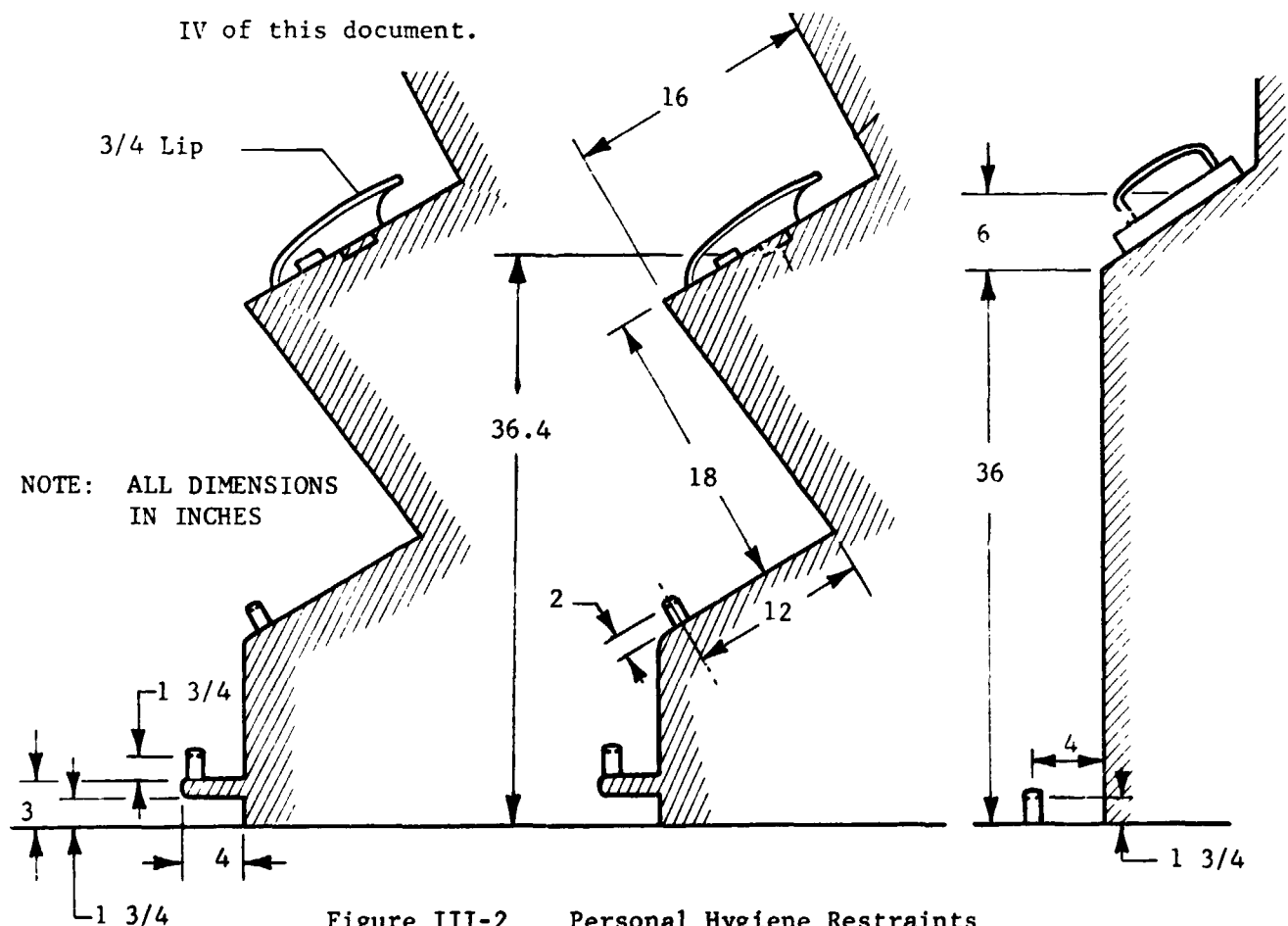


Figure III-1 Standing Restraints at a Counter

B. PERSONAL HYGIENE MODULE RESTRAINTS

In the personal hygiene module the tasks are specifically defined which dictates the body positions that require restraints. They are shown in Figure III-2. The body positions are standing at the urine/fecal collector and handwash unit, and sitting on the urine/fecal collector. The restraints/mobility aids associated with using the fecal collector are (1) hand hold on both sides of the fecal seat to assist in positioning the body on the seat; (2) retractable belt to go across the upper thighs allowing both hands to be free; and (3) a toe rail located on a surface that is parallel to the fecal seat and 16 inches below the fecal seat. The handwash unit requires a toerail as the primary restraint and a handhold on both sides of the hand-washer to help stabilize the body when approaching the unit and during the tasks of personal grooming. The requirements for the urinal restraints and handwash control valve are defined in Section IV of this document.



C. EQUIPMENT RESTRAINT CRITERIA

1. Equipment Lip Restraint/Mobility Aid

All furnishings and built-in equipment should incorporate a lip where possible to serve as a restraint/mobility aid. The lip shape should be such that a man using it as a handhold can exert a force that would torque the body around the point of contact. Typical examples would be on chairs, tables, cabinets and other furnishings and equipment as illustrated in Figure III-3.

NOTE: ALL DIMENSIONS IN INCHES

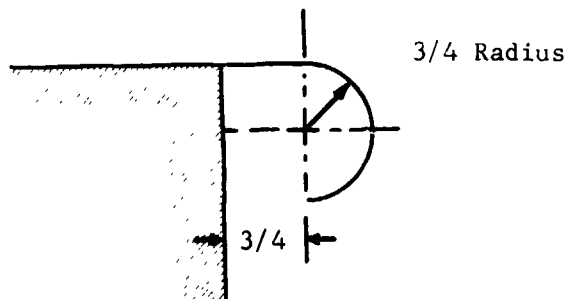


Figure III-3 Equipment Lip Restraint/Mobility Aid

2. Waste Material Restraint

A restraint is required in the retention of disposable items such as papers, tissues, and other waste materials in a zero gravity environment. These items can be retained within a compartment by an elastic material over the opening with a slit either diagonally or across the elastic material to allow easy access and yet retain all interior objects. Figure III-4 depicts this concept of a restraint.

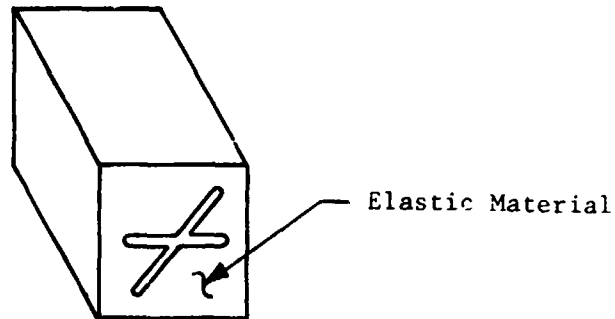


Figure III-4 Waste Material Restraint Concept

D. TEMPORARY STORAGE

In a zero-gravity environment all items should be secured at all times. This requirement dictates that temporary storage must be provided for objects of various sizes in all habitable areas. To satisfy this requirement a simple elastic cord such as bungee-cord against a surface will suffice. This concept is shown in Figure III-5.

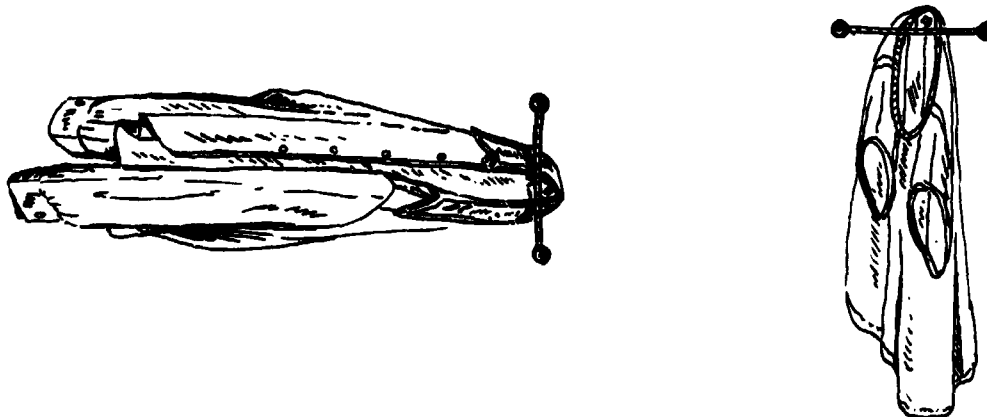


Figure III-5 Temporary Storage Restraint

E. AIRLOCK RESTRAINTS/MOBILITY AIDS

The tasks performed in the airlock dictate that special toerails and handholds are required to accommodate suited crewmen. When using the buddy-system during the donning/doffing of pressure suits, each crewman becomes a restraint/mobility aid in a sense in conjunction with the fixed restraints provided. The hatches on an airlock should be hinged on the same side to preserve a larger interior area for equipment and restraint/mobility aid placement. See Figure III-6.

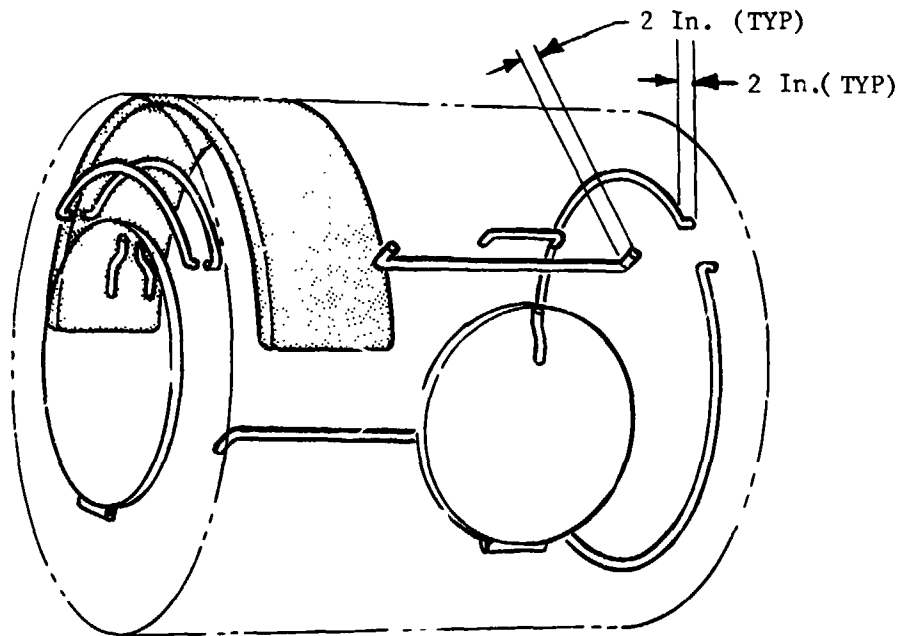


Figure III-6 Airlock Restraint/Mobility Aids

F. GENERAL RESTRAINT/MOBILITY AIDS

In a zero-gravity environment the technique employed to transfer from point-to-point is somewhat dependent upon the individual. However, the following methods can be used: (1) Orient the body to the path that will be traversed and then push-off with the feet with the arms extended (2) position the body with the hands and use the hands

to propel the body in the desired direction head first or feet first. When pushing off with the feet, use either the toerails or the surrounding equipment as the push-off point. When the hands are used, the handholds and furniture items are used as the mobility aid. Figure III-7 depicts these techniques of locomotion in a zero-gravity environment. It should also be noted that if a change in direction is required by the soaring crewman a specific handhold or equipment structure is required to allow the crewman to change his body motion.

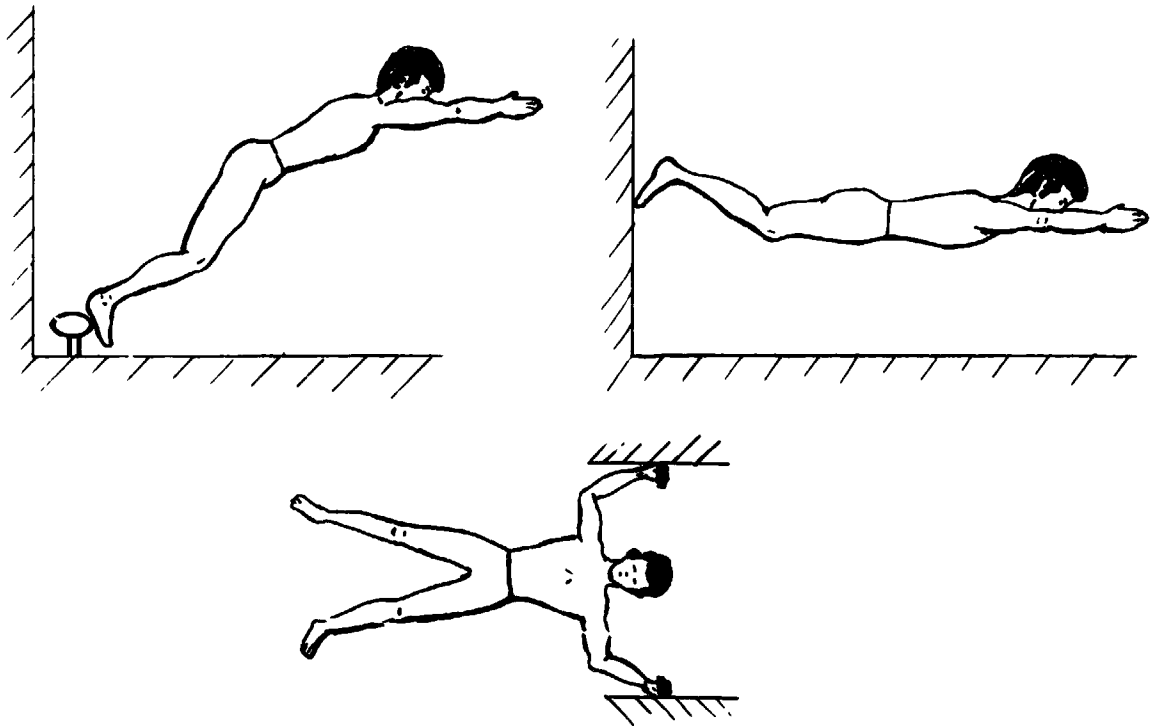


Figure III-7 Locomotion Techniques in Zero-Gravity

IV. MAN-MACHINE INTERFACE CRITERIA

A. MALE URINAL HEIGHT LOCATION

The male-urinal interface becomes a critical man-machine problem since free droplets of urine can create bacteria and machine problems. Therefore, it is necessary that the penile height correspond to the urinal opening. The vertical distance from the floor to the upper edge of the juncture of the penis with the abdomen varies from 31.6

inches to 37.4 inches for the 5 to 95 percentile males. Males can increase this height by 1.6 inches by raising up on their toes or they can decrease this height by bending the knees forward. When bending the knees forward to lower the penale height vertically one inch, the knees must move forward approximately three inches on the horizontal as shown in Figure IV-1.

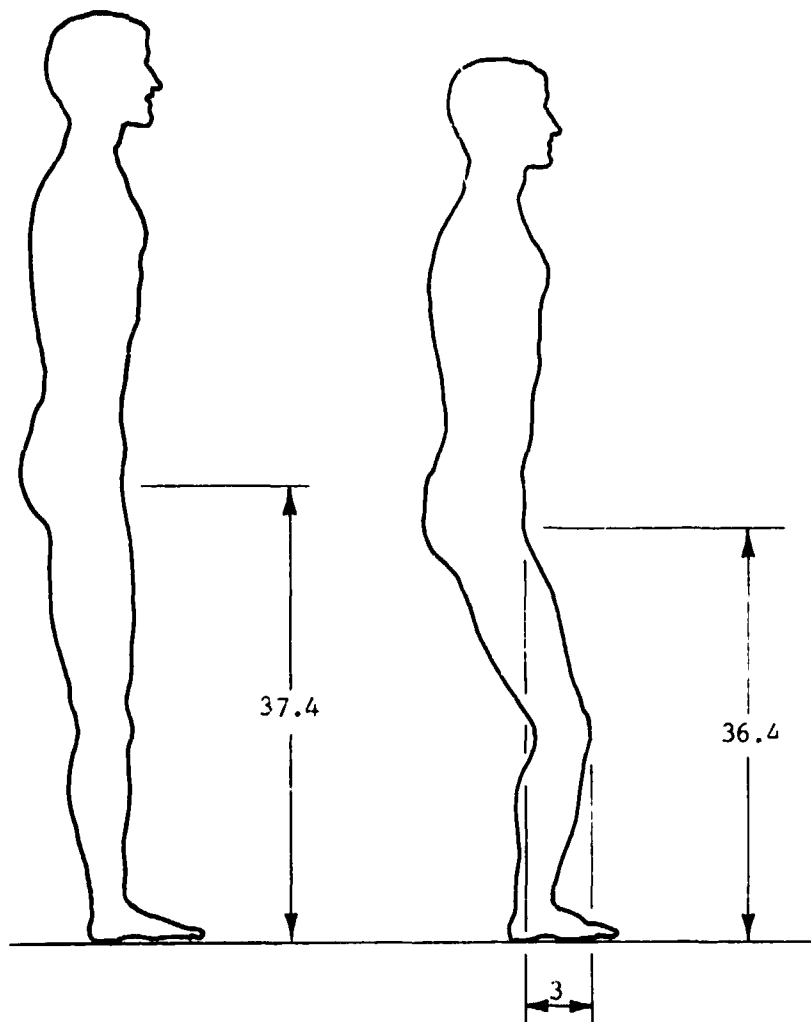


Figure IV-1 Knees Must Move Forward Three Inches
for Vertical Drop of One Inch

It can be readily seen that a fixed dimension will not satisfy the 5 to 95 percentile male. By locating the urinal height at 36.4 inches, and providing a two step foot restraint as shown in Figure IV-2, and providing a slope and recess for the knees as shown in Figure IV-3, the 5 to 95 percentile males can interface with a common urinal opening.

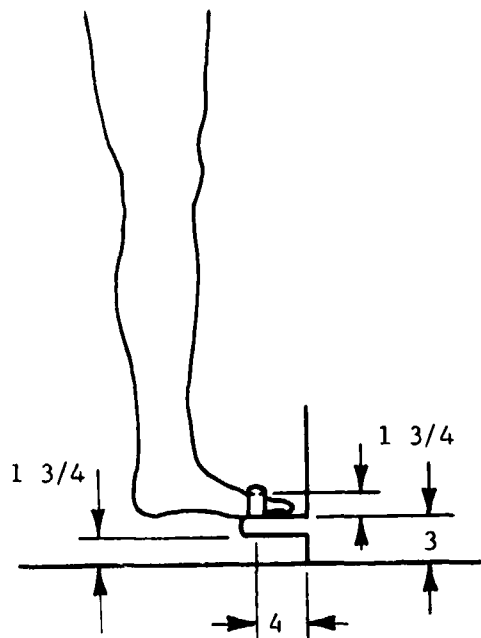


Figure IV-2 Two Step Foot Restraint to Allow Constant Urinal Height for 5 to 95 Percentile Males.

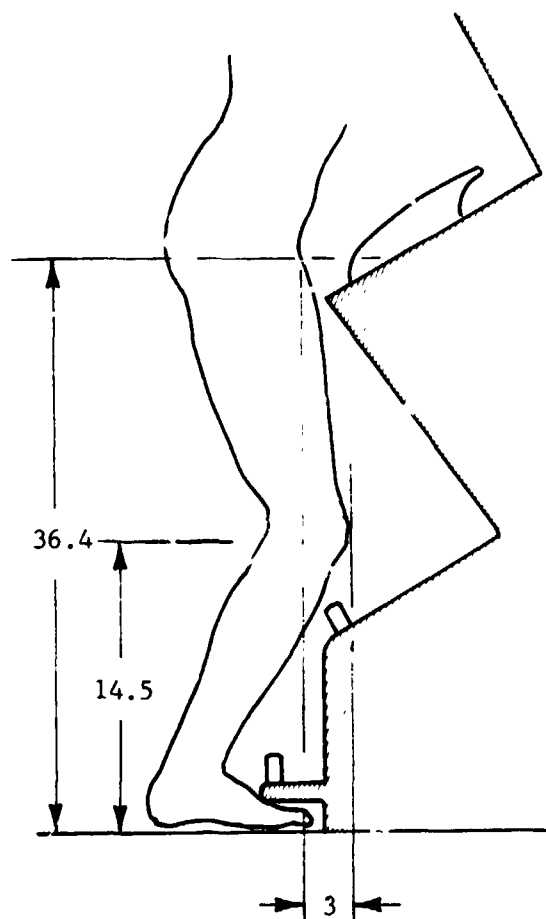


Figure IV-3 Slope & Recess Required Below Urinal Opening to Accommodate Lowering the Penile Height One Inch

B. MALE URINAL HAND RESTRAINT

When a male micturates, a specific three point restraint is necessary to assure that the man-machine interface is properly aligned. Proper alignment can be achieved by placing both feet under a toe bar and by placing one hand on a handhold directly behind and on the urinal opening centerline as shown in Figure IV-4. This restraint arrangement prevents torquing the body away from the urinal opening such as would be the case when utilizing a hand restraint on the side of the urinal.

NOTE:

Hand Restraint is Located Behind and on the Centerline of the Urinal Opening to Prevent Torquing the Body During Urination.

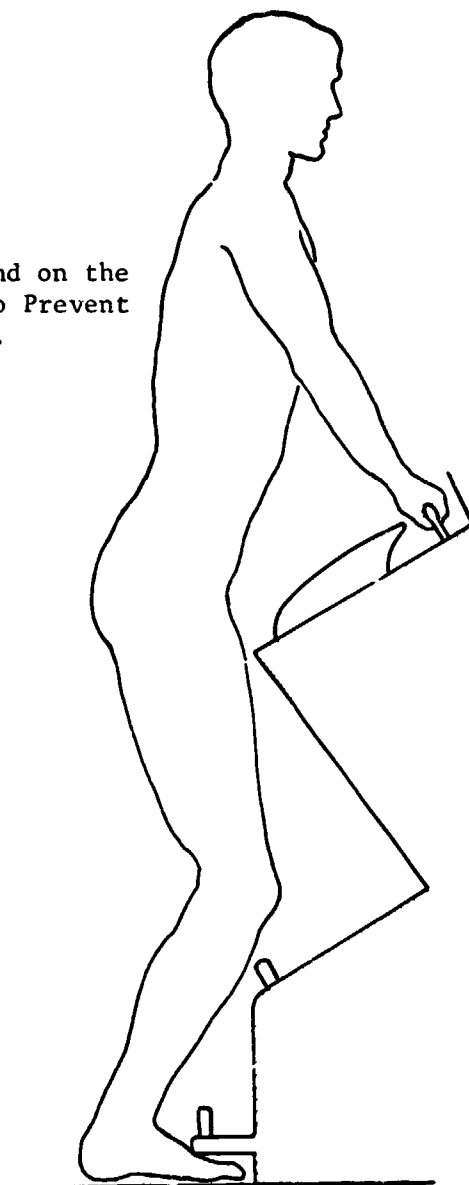
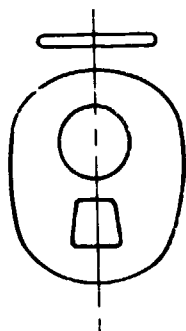


Figure IV-4 Urinal Hand Restraint

C. FOOT OPERATED LEVERS

In a zero-gravity environment, it is desirable to utilize foot operated levers for activation of systems so that the hands can be free to perform tasks. It must be realized that the feet are also utilized in restraints to stabilize the body. If the lever is activated by pushing down, the foot is being directed away from the foot restraint bar and the return spring action of the lever will torque the body away and around the opposite foot. This may be corrected by lifting the toes up to activate the lever. This allows the foot to remain in contact with the foot restraint and maintains body stability. See Figure IV-5.

NOTE: ALL DIMENSIONS
IN INCHES

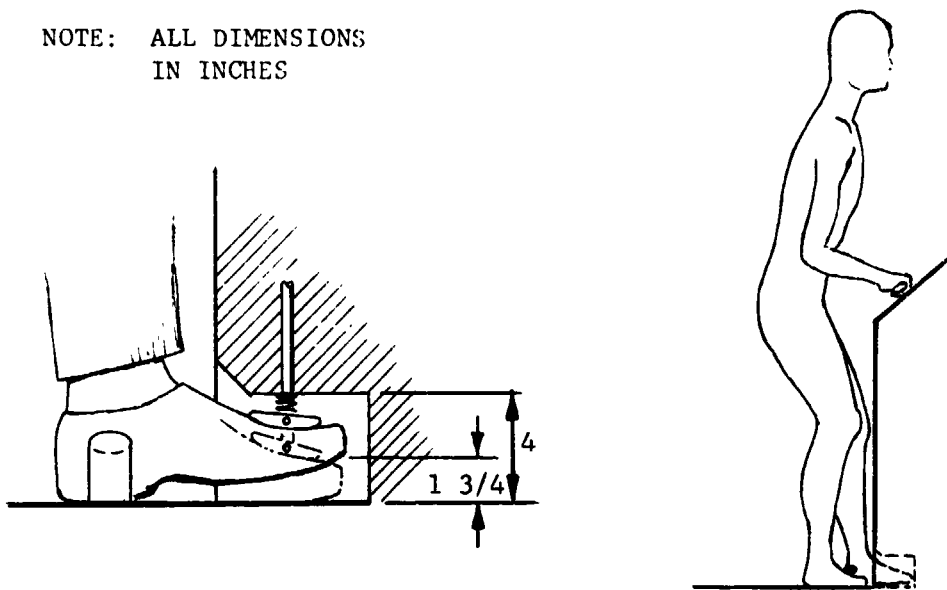


Figure IV-5 Foot Operated Lever is Activated by Lifting Up With Toe thus Keeping the Foot in Contact with the Toe Bar for Body Stability.

D. STOWAGE AND WORK AREA ACCESSIBILITY/VISIBILITY REQUIREMENTS

When utilizing toe rails accessibility and visibility of contents in cabinets located below the knee level (22 inches) should be provided by pull-out drawers when the crewman is restrained by a toe bar. This is illustrated in Figure IV-6.

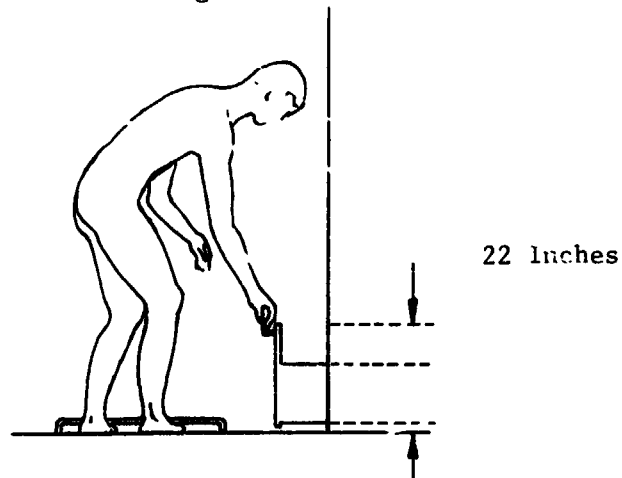


Figure IV-6 Utilize Pull-Out Drawers Below Knee Level for Better Accessibility and Visibility of Contents When in Restraints Position.

Accessability and visibility for storage areas above 54 inches should be provided by swing-out doors as shown in Figure IV-7.

NOTE: ALL DIMENSIONS
IN INCHES

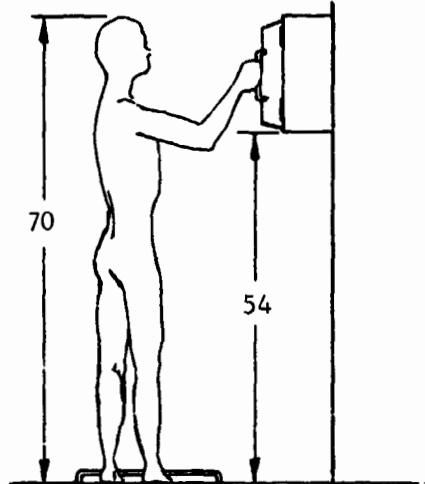


Figure IV-7 Utilize Swing-Out Doors above 54 Inches

Doors that are required to swing-out, such as refrigerators and freezers, should be located above the knee level (22 inches) so that the feet do not have to be repositioned. This point is illustrated in Figure IV-8.

NOTE: ALL DIMENSIONS
IN INCHES

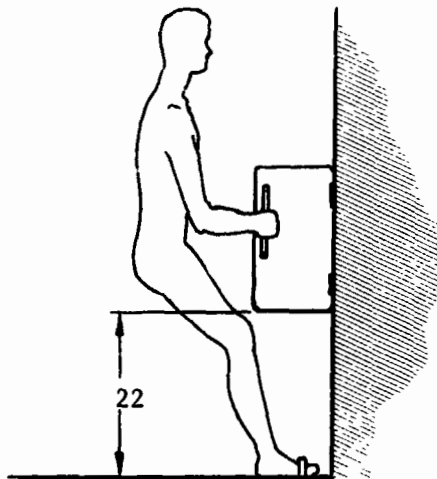
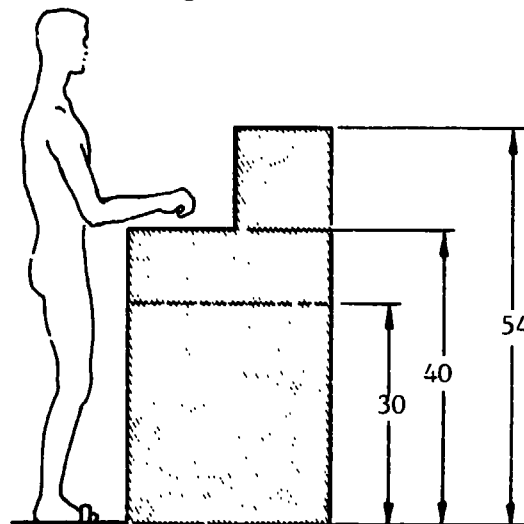


Figure IV-8 Swing-Out Doors Should be Located 22 Inches Above Floor to Avoid Contact With Knees of Restrained Personnel.

For efficient accessibility and visibility high usage areas and equipment should be placed between 30 and 54 inches from the floor and counter space should be located 40 inches above the floor. These points are illustrated in Figure IV-9.



NOTE: ALL DIMENSIONS
IN INCHES

Figure IV-9 Dimensions for Counter and High Usage Equipment.

E. DOORS

Doors such as a personal hygiene privacy door, should be designed to incorporate mobility/restraint aids to allow ingress/egress through the opening without separate aids. This could be accomplished by utilizing a split door that allows each half to slide laterally opposite the other half. Each half of the door should contain a hand restraint on both sides of the half door as defined in III-A. This will permit a crewman to open the door, ingress/egress through the opening and then close the door. This complete sequence is accomplished by utilizing the hands only. The split doors (tambour) provide the crewman with equal opposing forces thus aiding in stabilization. See Figure IV-10.

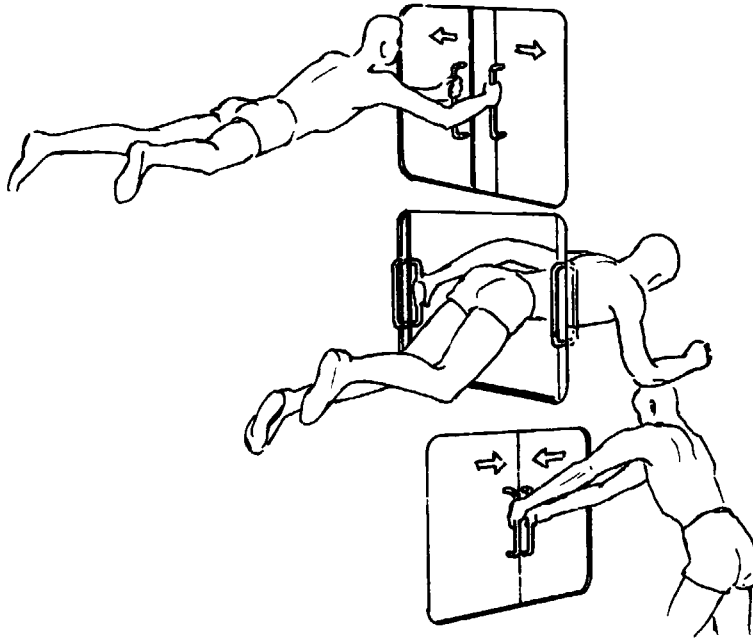


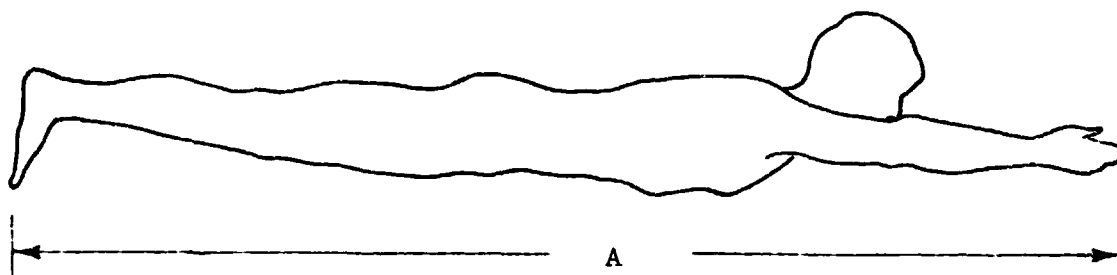
Figure IV-10 Crewman Ingressing Private Area Utilizing Split Door with Hand Restraints on Both Sides of Each Half.

V. ZERO-GRAVITY MAN MODEL DEFINITION

The following data further defines the characteristics of a man in a zero-gravity environment. This definition is provided to make the designer aware of man's actions in this environment which could effect the man-machine interface design.

A. TRANSLATION IN LARGE VOLUME

During translation along a path greater than the body stature length, the subject usually pushes off with his feet, soars approximately parallel to the defined path with his head tilted back such that his eyes are also parallel to the path. The arms and hands are extended parallel to the path which in effect lengthens the body envelope dimensions. This is illustrated in figure V-1.



A= 81.5 inches for 5 percentile

A= 92.4 inches for 95 percentile

Figure V-1 5 and 95 Percentile Length During Zero-Gravity Soaring

B. TRANSLATION IN SMALL VOLUME

Zero-gravity maneuvering in a small volume, such as a personal hygiene module is usually accomplished with the body orientated to the task to be accomplished. The hands and arms are used extensively during the maneuvers with the feet utilized only for restraint and stabilization.

C. DEGREES OF MOTION

Five degrees of body motion are primarily utilized in the locomotion process. These are translation in X, Y and Z planes, pitch about x-axis and yaw about the z-axis. Roll about the y-axis is seldom utilized. See Figure V-2.

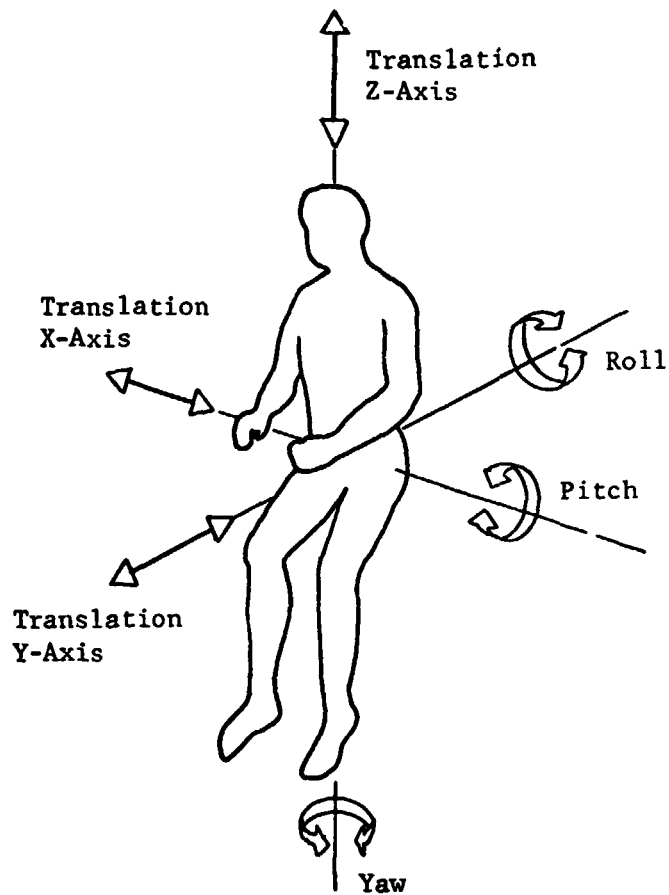


Figure V-2 Degrees of Motion Possibilities

D. MOBILITY/RESTRAINT

In a zero-gravity environment the hands and arms are utilized to a greater extent during locomotion than in one gravity. The feet are normally utilized as mobility aids for propelling, whereas the hands are utilized for guidance.

E. ONE-GRAVITY VERSUS ZERO-GRAVITY USAGE OF LIMBS

In one-gravity, the heels and ball of the feet are utilized during the locomotion and stabilization process. In zero gravity, the heels of the feet are utilized less and the ball of the foot and the toes are utilized more. See Figure V-3. During zero-gravity stabilization, the leg muscles are utilized much more than in one gravity standing. The calf and upper leg muscles are primarily affected.

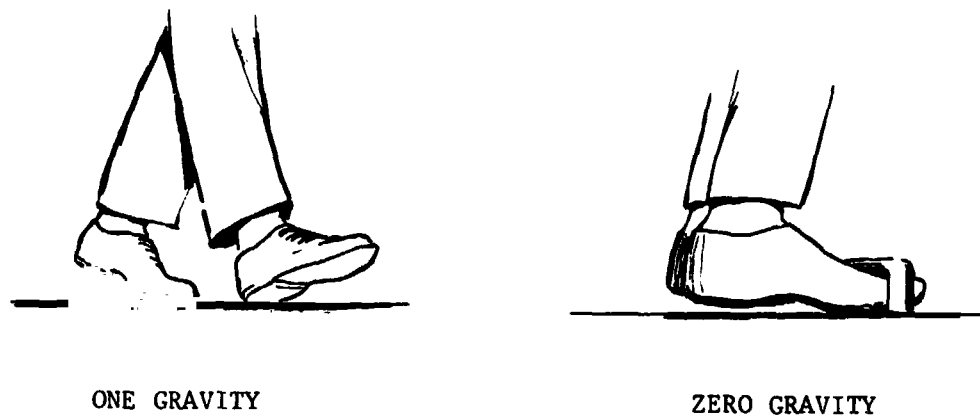


Figure V-3 One-Gravity Stabilization Versus
Zero-Gravity Stabilization

F. TASK TIMELINES

Times required to perform tasks in zero gravity are generally slower than performing the same task in one gravity. This is due to being more deliberate in the performance of the task in order to maintain control of body stabilization.

G. INCREASE STATURE HEIGHT

In the absence of gravity, actual body measurements of the stature height is increased. Neutrally buoyant conditions increase the stature height as much as 5/8 of an inch. In true zero gravity, this stature height may be increased even more.

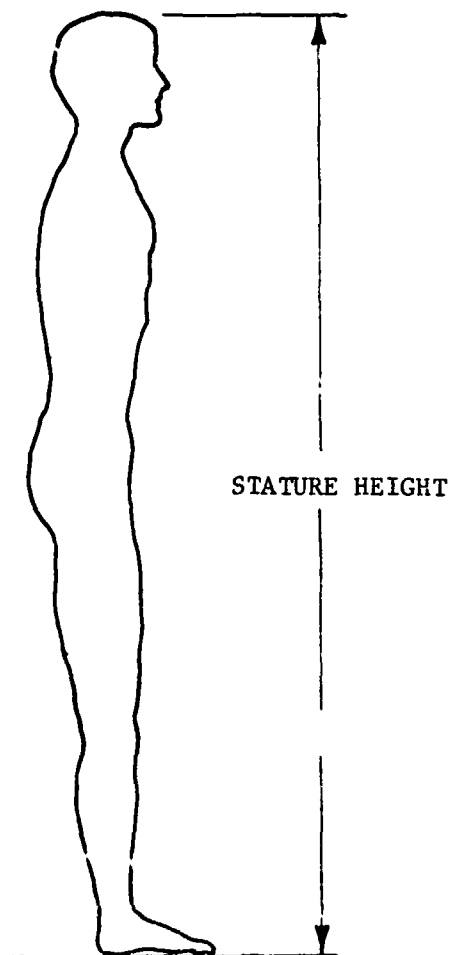


Figure V-4 Stature Height Increases as Much as 5/8 of an Inch During Neutrally Buoyant Conditions

VI. VOLUME REQUIREMENTS

This section will define the general volume for the habitability modules and areas and the access volume required for the man-machine interface.

A. GROSS VOLUME

In determining the gross volume for a given room, all activities and tasks which are to be conducted within the room must be defined. From these activities and tasks the equipment volume and storage volumes are determined to make up the gross volume. If a room is designed for multiple orientations in order that maximum volume utilization occur, sufficient space must be provided to allow for changes in orientation to be accomplished. To minimize total volume requirements, related tasks should be grouped together to utilize shared access volume.

B. ACCESS VOLUME

The volume interface requirements between man and the furniture or equipment is identified as the access volume. These individual volume requirements are not necessarily additive for gross volume definitions, because they may be shared. The access envelopes defined in Supplement 1 are all applicable and the only example for this Supplement will be for the couches mounted in the vehicle z-axis and is shown in Figures VI-1 and VI-2.

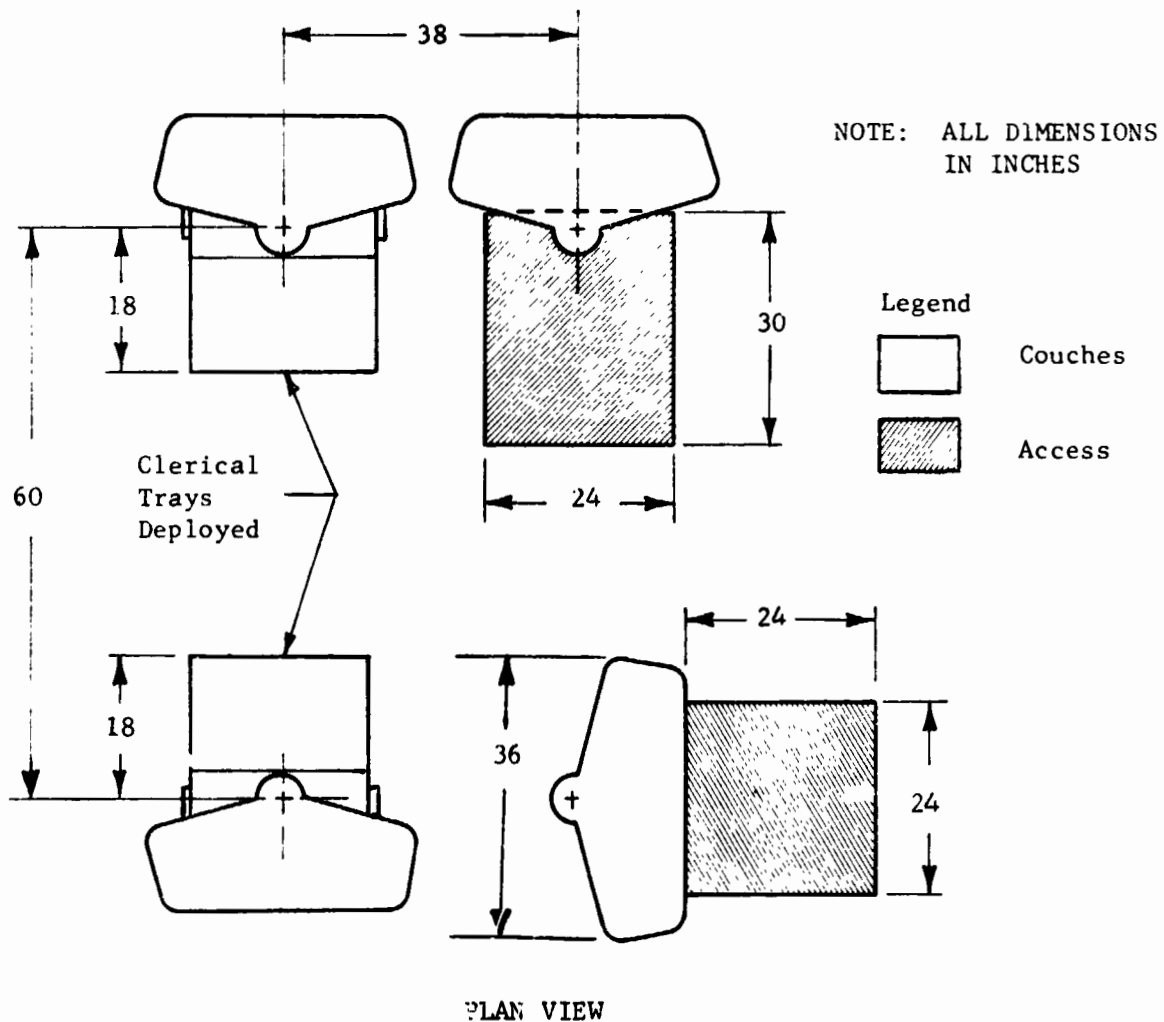


Figure VI-1 Multiple Couches and Access Envelopes

NOTE: ALL DIMENSIONS
IN INCHES

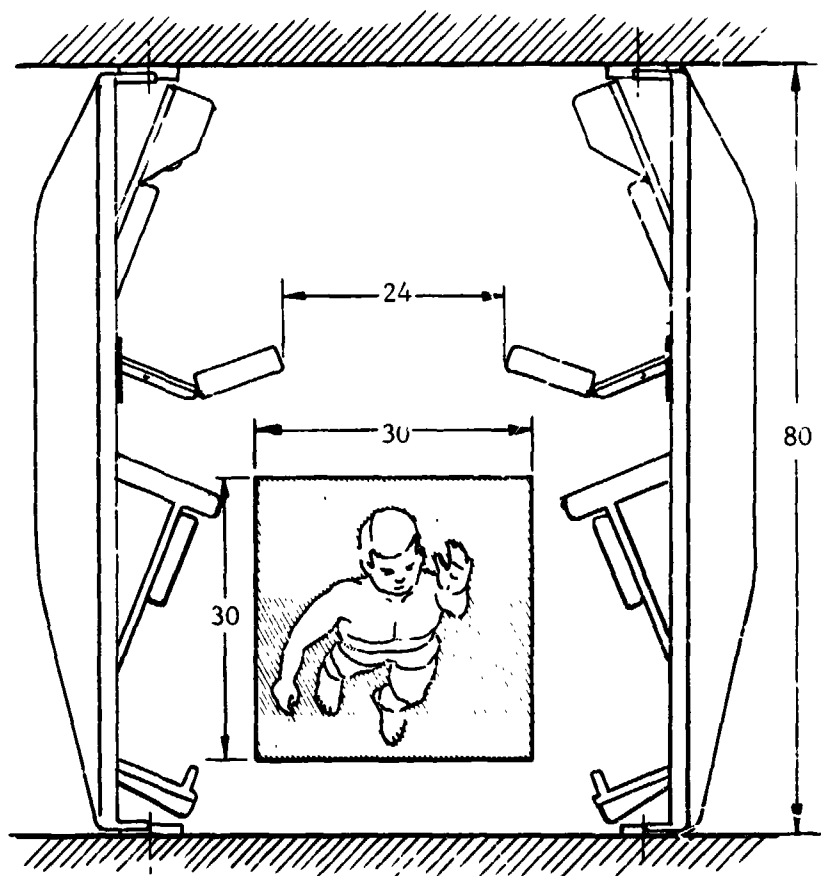


Figure VI-2 Translation Between Couches